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MAGNETIC SURVEY DATA AVAILABLE PRIOR TO THE WORLD MAGNETIC SURVEY EFFORT OF THE IQSY

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ABSTRACT

Given are the distributions of magnetic survey information available from all sources since 1900. The data are tallied according to distribution by area and decade, and according to component measured. Recommendations are made on the basis of these studies for specific surveys during the IQSY. (1964.0 - 1966.0)

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1. Number of observations per $10^{5}km^{2}$ (data 1900-1961)
2. Number of observations per $10^{5}km^{2}$ (data since 1955.0)

I. INTRODUCTION

In an attempt to obtain the most accurate reference field possible for future use in reducing satellite data, all available magnetic survey data are being collected for incorporation into a computer program that produces a set of spherical harmonic coefficients which fit the data. The purpose of this report is to assess the data presently available and to make recommendations for additional acquisitions.

II. SOURCES

The major portion of the present information has been supplied by the U. S. Coast and Geodetic Survey which provided a punched card copy of the data from which their 1955 charts were derived. These are observations dating from 1900 which have been accrued from approximately 500 sources. As with all data in this report, an attempt was made to differentiate between originally observed values and those which were computed, so that the basic data would consist only of observed values. Due to the wide variety of sources, this deletion was not always feasible but, on the basis of the information available, some editing was done as follows:

(1) The horizontal and vertical intensity values were eliminated from USCGS measurements,

(2) In addition, the vertical intensity value was dropped from surface observations if a particular datum contained values for inclination and horizontal intensity, and was from a source other than a U. S. observatory.

Since analysis of these observations will also involve studies of secular change, it was deemed desirable to delete values which had been reduced to epoch. On the basis of this premise some 21,300 observations from a Russian publication* which had been reduced to epoch 1940 were removed from the main block of data with the hope that it may be possible to replace them with the original data.

Data were also received from the U. S. Oceanographic Office. These 32,000 observations were the result of Project Magnet, an airborne survey in which measurements of F, I, and D were averaged over five minute intervals along track lines covering most of the northern hemisphere other than the Soviet Union and China.

A third source of information was the Canadian Department of Mines and Technical Surveys which, since 1953, has conducted an airborne survey, mainly in that North American area, resulting in nearly 12,000 H, Z, and D observations (5 minute averages).

The Geophysical and Polar Research Institute of the University of Wisconsin has provided about 2400 observations of total field in the area around the South Pole.

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* Compounded systematic catalog of magnetic determinations of the general magnetic survey of the USSR, 1931-1942, Scientific Research Institute of Terrestrial Magnetism, 1947.

The Southern and Indian Oceans, and the South China Sea were surveyed by the Japanese Antarctic Research Expedition with a ship-towed magnetometer. Their report (Nagata, et al, 1961) supplied another 5000 observations of total field, approximately half of which have been incorporated in this summary.

Total field measurements from the Vanguard III satellite (1959 Eta) comprised the sixth major source of data. The 85 day active life of the proton precession magnetometer provided 2797 observations over South America, Southern Africa, Australia, California, and the east coast of the U. S. (Cain, et al, 1962).

III. DATA PENDING

In addition to the data covered by this report, a set of total field readings obtained on cruises of the R/V Vema from 1959-62 and compiled by Lamont Geological Observatory are currently being processed. This will add 3600 observations in southern ocean areas.

Arrangements are being made in conjunction with the USCGS to receive from the Geophysical and Polar Research Institute of the University of Wisconsin a more recent series of total field observations in the Arctic and Antarctic areas.

IV. DISTRIBUTIONS OF DATA

The above sources of data were converted to a standard format and recorded on magnetic tape. Each of the 152,424 observations was written with information regarding its position (latitude and longitude in degrees, altitude in kilometers) and time (in Julian

days and fractions of a day since 1900), plus the measured values for one or more components of the magnetic field. This tape was scanned and the data were tabulated in the following ways:

(1) By component and area - Tables 1 (a) through 1 (e) show the number of points in each 10^{o} x 10^{o} block of latitude and longitude for observations of declination, inclination, horizontal intensity, vertical intensity, and total field. Longitude numbers refer to the eastern boundary of the block (i.e. the longitude block labeled-160 extends from 170^{o}W to 160^{o}W). The values from these five tables were combined to give the totals which appear in Table 1 (f).

(2) By decade and area - In order to determine how frequently and how recently a particular region had been covered, the data were divided into 10 year blocks and the latitude - longitude distribution was compiled for each decade. Table 2 (a through g) displays these figures which, as with Table 1 (f), represent the sum of all component measurements. Most of the polar data has been accrued since 1950 and, although the total number of points (57527) already accumulated in the present decade is great in comparison with previous years, there are vast regions over the ocean areas and over the Soviet Union where no new data are available.

(3) By year - A more general breakdown in time is given

in Table 3 where the number of points for each component is tallied for each year.

(4) By altitude - Although the preponderance of data are surface observations, recent airborne surveys have supplied considerable data up to 7 or 8 kilometers. This distribution is shown in Table 4. Total field measurements taken by the Vanguard III satellite provided data in the region from 510 to 3750 km. altitude (Cain, et.al., 1962).

V. DENSITIES OF DATA

The large difference between the amount of surface area covered by a 10^{o} square at the equator and a similar square in polar regions made it desirable to use another method for illustrating distributions. The number of square kilometers in each block was calculated using the formula:

$$A = \frac{2\pi R}{360/\Delta\varphi} \left[\sin(\theta + \Delta\theta) - \sin\theta\right]$$

where R (earth's radius) was taken to be 6371.2 km, $\Delta\varphi$ and $\Delta\theta$ were 10^{o}, and θ was the latitude of the southern boundary of the block. These areas are listed in Table 5. Dividing the number of points in each block of Table 1 (f) by the area A for that block gave the number of observations per square kilometer. These figures were multiplied by a scale factor of 10^{5} to produce the results displayed in Figure 1.

DECLINATION

NO. OF OBSERVATIONS= 115966.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	30	56	18	20	34	30	185	137	46	33	63	42	14	320	53	37	3	
-160	3	127	6	12	4	6	51	87	53	111	122	117	35	33	443	198	79	49	
-150	4	32	1	8	6	4	30	121	98	89	169	731	51	43	382	200	126	68	
-140	1	5	3	1	9	19	15	92	12	29	31	322	86	125	169	578	120	25	
-130	0	2	3	0	11	28	26	14	11	10	56	170	258	194	1239	415	91	22	
-120	0	0	2	8	5	15	14	26	6	15	62	64	653	1648	1173	427	83	25	
-110	0	0	0	4	3	24	19	30	14	22	78	102	962	1311	6889	639	88	49	
-100	0	0	0	10	5	34	25	16	74	58	105	160	801	1319	5405	317	157	135	
-90	0	0	0	15	9	31	43	19	87	67	312	530	1384	1518	2398	362	160	378	
-80	0	0	0	19	6	45	49	65	112	225	340	734	1964	1682	527	228	173	148	
-70	0	6	2	65	34	170	88	505	255	474	516	494	1425	2426	550	323	163	61	
-60	0	26	89	77	85	437	128	153	147	246	869	409	875	1191	593	276	188	42	
-50	0	1	64	56	13	307	142	126	161	268	245	247	544	611	535	253	95	16	
-40	0	50	57	3	11	22	297	119	285	130	148	136	332	141	366	190	74	16	
-30	0	20	6	17	4	15	33	157	442	63	160	121	290	130	174	301	67	16	
-20	0	8	0	3	6	3	46	112	197	134	272	179	428	250	169	410	87	21	
-10	0	0	0	3	6	17	16	109	92	283	188	209	380	182	311	186	74	28	
0	0	0	0	4	9	23	11	105	80	163	279	186	704	934	895	121	70	19	
10	0	0	0	9	3	31	30	42	109	138	219	889	656	419	736	687	30	6	
20	0	0	0	4	0	413	209	193	216	252	131	257	238	335	524	2547	88	0	
30	0	0	0	3	1	824	638	267	149	170	46	30	182	137	350	3242	415	4	
40	0	0	20	5	12	22	372	188	484	267	102	377	390	23	68	673	21	2	
50	0	0	1	3	10	9	298	780	80	142	174	28	141	39	49	201	12	0	
60	0	0	0	0	8	5	82	109	83	85	146	109	95	0	0	87	50	36	
70	0	0	3	2	34	1	29	30	91	77	129	452	108	21	57	84	14	0	
80	0	0	4	23	5	25	17	38	168	302	1014	420	583	0	0	61	17	0	
90	0	0	18	5	12	8	10	5	69	137	152	506	47	3	8	48	34	2	
100	0	1	27	1	5	26	10	22	85	91	390	233	108	8	0	9	13	2	
110	0	0	2	9	14	8	59	21	195	209	334	375	400	1	76	14	148	0	
120	0	0	2	12	22	354	82	29	108	126	106	632	0	1	0	6	5	0	
130	0	0	0	4	46	47	42	70	84	137	346	320	149	9	2	46	20	1	
140	0	0	2	19	32	202	114	171	155	116	35	72	189	11	0	24	11	0	
150	0	12	131	40	105	253	131	134	72	92	277	111	121	79	94	24	23	0	
160	5	32	10	43	42	248	216	63	82	54	95	45	1	117	82	35	121	0	
170	25	260	57	75	254	130	68	24	59	78	80	75	1	119	103	68	295	0	
180	3	97	8	41	865	581	170	172	53	58	60	50	35	14	181	8	122	0	

TABLE 1 (a)

INCLINATION

NO. OF OBSERVATIONS= 73414.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	12	27	14	11	34	26	161	164	37	60	93	68	19	204	63	39	2	
-160	3	101	0	3	4	4	44	27	53	150	157	113	46	56	161	125	71	29	
-150	3	14	1	2	4	6	19	57	39	46	149	610	46	61	177	183	91	41	
-140	1	4	1	0	6	13	7	76	8	13	26	282	80	144	125	271	79	22	
-130	0	1	2	0	8	19	17	5	7	7	49	167	204	205	295	123	91	21	
-120	0	0	1	2	3	11	7	12	3	13	67	65	496	570	136	47	82	30	
-110	0	0	0	2	2	14	9	12	9	15	76	99	676	537	396	57	76	36	
-100	0	0	0	4	5	22	8	6	72	71	117	144	678	474	405	29	181	29	
-90	0	0	0	5	8	31	45	7	78	68	286	425	1089	1036	150	59	138	20	
-80	0	0	0	10	4	33	39	71	101	94	245	555	1713	1009	90	10	119	24	
-70	0	0	1	45	20	128	71	395	169	300	445	497	1189	1379	30	91	137	41	
-60	0	0	19	48	35	266	60	120	139	191	812	427	782	707	120	41	124	28	
-50	0	0	29	56	6	129	92	133	189	278	308	253	405	441	276	137	86	16	
-40	0	63	83	5	4	13	265	129	262	163	205	130	373	191	327	118	53	22	
-30	0	10	1	9	2	4	37	132	455	66	198	122	363	145	199	221	63	18	
-20	0	0	0	4	5	1	23	97	210	144	322	185	495	276	174	309	63	21	
-10	0	0	0	2	10	8	7	103	83	286	184	210	414	172	233	110	61	35	
0	0	0	0	2	7	10	5	120	78	127	96	73	514	431	778	88	74	19	
10	0	0	0	2	3	17	12	42	125	117	133	304	295	315	750	98	33	6	
20	0	0	0	2	0	314	128	224	153	195	78	115	214	369	697	247	22	0	
30	0	0	0	2	0	514	432	249	50	102	32	30	189	246	627	1649	61	2	
40	0	0	6	3	3	15	258	166	312	207	74	346	266	49	83	378	2	0	
50	0	0	1	1	2	5	81	369	92	122	178	38	139	43	50	171	0	0	
60	0	0	0	0	3	3	82	121	48	87	136	93	99	0	1	70	34	25	
70	0	0	1	0	19	0	9	36	89	81	126	647	97	26	62	62	5	0	
80	0	0	0	12	0	10	9	37	203	320	1015	413	569	13	11	46	1	0	
90	0	0	3	0	4	3	3	2	119	154	187	535	56	8	31	38	29	0	
100	0	0	8	0	0	16	4	19	135	101	462	222	108	2	3	2	13	0	
110	0	0	0	4	4	4	63	6	226	250	377	177	220	5	77	0	203	0	
120	0	0	1	4	22	281	90	31	120	122	130	380	66	10	0	0	1	0	
130	0	0	0	0	38	39	40	79	105	85	289	194	209	11	1	24	11	0	
140	0	0	3	6	40	179	113	147	97	71	45	103	203	12	1	11	7	0	
150	0	8	102	40	126	244	98	73	105	136	293	110	234	88	45	26	16	0	
160	0	18	2	40	73	195	176	64	106	66	86	87	7	150	20	28	99	0	
170	0	66	30	33	276	105	69	24	57	83	67	127	13	135	36	50	173	0	
180	0	47	0	24	699	565	144	164	48	63	57	65	49	23	92	15	86	0	

TABLE 1 (b)

HORIZONTAL

NO. OF OBSERVATIONS= 54291.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	0	0	4	11	9	14	167	15	8	2	6	5	8	37	46	11	0	
-160	2	81	0	3	5	4	8	65	9	9	9	19	14	9	48	34	0	0	
-150	3	9	1	2	4	5	18	72	53	61	93	347	6	5	39	33	21	0	
-140	1	4	1	0	6	13	7	74	8	13	7	64	14	3	47	232	6	0	
-130	0	1	2	0	8	18	17	5	8	7	13	23	63	24	309	265	15	0	
-120	0	0	1	2	3	11	7	12	3	13	6	9	206	418	441	198	9	0	
-110	0	0	0	2	2	14	9	12	9	15	14	25	278	487	989	261	11	0	
-100	0	0	0	4	5	22	10	6	6	9	30	107	431	463	972	249	40	0	
-90	0	0	0	5	7	10	7	7	14	14	198	171	863	1102	751	303	53	18	
-80	0	0	0	10	4	10	15	12	36	81	188	260	1284	1213	516	224	80	4	
-70	0	0	1	49	21	96	37	321	185	300	133	81	596	1680	562	303	92	3	
-60	0	0	62	51	35	263	68	90	91	114	371	10	479	908	588	238	101	19	
-50	0	0	44	58	6	111	76	68	71	90	27	8	210	377	379	155	32	1	
-40	0	71	84	5	4	13	186	71	112	7	14	12	37	26	181	95	0	0	
-30	0	14	2	10	2	4	6	60	48	13	16	11	18	9	73	94	0	0	
-20	0	5	0	4	5	1	7	7	0	4	8	5	70	7	66	139	23	0	
-10	0	0	0	2	10	8	5	7	6	34	52	54	20	15	155	59	7	2	
0	0	0	0	2	7	10	5	36	5	66	52	27	408	275	637	65	6	10	
10	0	0	0	2	3	17	12	7	10	96	63	377	385	263	725	616	5	6	
20	0	0	0	2	0	340	145	82	117	116	63	118	54	352	708	1117	43	0	
30	0	0	0	2	0	456	391	167	52	87	32	6	55	231	704	1742	334	1	
40	0	0	22	3	3	13	176	144	329	126	68	253	246	46	79	392	16	0	
50	0	0	1	1	2	5	174	529	2	12	19	6	108	48	50	185	15	0	
60	0	0	0	0	3	3	69	16	15	5	3	12	71	0	1	72	37	25	
70	0	0	1	0	20	0	9	3	4	5	7	90	58	22	66	71	7	2	
80	0	0	0	13	0	10	9	6	4	157	823	386	570	3	11	61	5	1	
90	0	0	2	0	4	3	3	2	7	51	71	458	70	18	73	39	32	2	
100	0	1	10	0	0	16	4	11	8	44	326	203	121	3	18	1	19	1	
110	0	0	1	4	4	4	3	16	176	57	233	248	235	4	79	0	245	0	
120	0	0	2	4	1	311	46	3	47	19	14	454	12	3	0	1	1	0	
130	0	0	0	0	9	44	40	29	37	67	155	139	149	1	1	37	12	0	
140	0	0	1	6	7	174	68	115	67	56	7	15	157	12	0	13	7	0	
150	0	2	108	5	68	197	102	99	21	11	70	45	103	62	30	26	16	0	
160	0	0	0	20	2	157	84	15	21	29	9	0	6	35	20	28	108	0	
170	0	47	0	10	185	40	26	24	26	32	25	11	8	49	20	54	203	0	
180	0	1	0	0	730	412	57	55	39	13	11	7	3	6	31	14	97	0	

TABLE 1 (c)

VERTICAL

NO. OF OBSERVATIONS= 17325.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	0	0	0	0	0	2	70	0	0	0	0	0	0	29	0	0	0	
-160	0	6	0	0	0	0	0	44	0	0	0	0	0	0	28	6	0	0	
-150	0	0	0	0	0	0	0	58	39	39	47	126	0	0	17	7	8	0	
-140	0	0	0	0	0	0	0	0	0	0	0	52	0	0	44	162	5	0	
-130	0	0	0	0	0	0	0	0	0	0	0	3	53	12	225	232	16	0	
-120	0	0	0	0	0	0	0	0	0	0	0	0	51	121	344	185	7	0	
-110	0	0	0	0	0	0	0	0	0	0	0	0	58	77	663	249	4	0	
-100	0	0	0	0	0	0	0	0	0	0	3	0	1	93	566	263	36	0	
-90	0	0	0	0	0	0	0	0	0	0	30	1	13	186	601	316	51	0	
-80	0	0	0	0	0	0	0	0	0	0	0	6	0	338	442	227	63	0	
-70	0	0	0	7	1	0	0	28	0	4	0	1	100	535	520	221	40	3	
-60	0	0	81	15	0	43	21	0	0	0	77	0	226	528	509	207	84	20	
-50	0	0	56	0	0	0	0	0	0	0	0	0	192	304	281	140	28	0	
-40	0	4	16	0	0	0	46	0	5	0	0	0	21	14	177	84	0	0	
-30	0	5	0	0	0	0	0	0	0	0	0	0	0	0	69	91	0	0	
-20	0	5	0	0	0	0	0	0	0	0	0	0	46	0	63	116	0	0	
-10	0	0	0	0	0	0	0	0	0	1	4	0	0	0	146	53	0	0	
0	0	0	0	0	0	0	0	0	0	2	0	1	72	85	255	51	1	0	
10	0	0	0	0	0	0	0	0	0	2	0	9	13	115	313	569	0	0	
20	0	0	0	0	0	35	12	2	9	1	0	15	6	124	243	951	25	0	
30	0	0	0	0	0	15	22	18	0	0	0	0	9	12	68	136	244	0	
40	0	0	16	0	0	0	15	1	0	0	0	63	48	18	65	13	14	0	
50	0	0	0	0	0	0	108	213	0	1	0	0	0	39	47	0	0	0	
60	0	0	0	0	0	0	55	8	0	0	0	0	0	0	0	0	6	11	
70	0	0	1	0	9	0	0	0	0	0	0	0	4	20	55	0	0	0	
80	0	0	0	6	0	0	0	0	0	0	88	4	100	0	0	0	0	0	
90	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	11	0	
100	0	1	1	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	
110	0	0	0	0	0	0	0	0	51	6	1	21	0	0	68	0	7	0	
120	0	0	1	0	0	36	0	0	0	5	0	56	0	0	0	0	0	0	
130	0	0	0	0	0	0	0	0	0	37	85	41	118	0	0	9	0	0	
140	0	0	0	0	0	0	0	17	44	31	0	6	45	5	0	0	0	0	
150	0	0	1	0	0	35	5	48	1	0	0	0	63	22	0	0	0	0	
160	0	0	0	6	0	44	40	0	0	0	0	0	0	28	0	10	0	0	
170	0	23	0	0	0	36	0	0	0	0	0	0	0	32	4	0	0	0	
180	0	0	0	0	45	41	46	14	0	0	0	0	0	0	24	0	0	0	

TABLE 1 (d)

TOTAL FIELD

NO. OF OBSERVATIONS= 45015.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	7	34	10	0	26	15	49	155	34	58	109	65	11	202	22	28	2	
-160	0	0	0	0	0	0	40	5	46	146	151	100	32	48	140	91	71	30	
-150	0	0	0	0	0	0	0	48	26	26	113	394	40	59	166	157	71	42	
-140	0	0	0	0	0	0	0	0	0	0	21	274	66	150	133	171	78	22	
-130	0	0	0	0	0	0	0	0	0	0	41	153	199	194	115	83	92	22	
-120	67	0	0	0	0	0	0	0	0	0	63	62	411	279	37	25	80	31	
-110	474	512	0	0	0	0	0	0	0	0	95	296	755	143	26	33	71	41	
-100	165	449	0	0	0	0	0	0	74	65	99	41	273	126	29	23	198	30	
-90	118	454	0	0	0	26	41	0	69	57	114	278	279	136	10	36	127	20	
-80	75	99	0	0	0	25	30	69	81	21	94	320	507	144	38	0	95	31	
-70	16	0	0	0	0	214	194	293	158	103	370	522	940	247	0	0	84	44	
-60	0	0	0	0	0	167	85	44	68	113	637	573	654	372	32	4	110	27	
-50	0	0	0	0	0	34	18	70	133	193	297	251	404	420	184	92	81	15	
-40	0	0	0	0	0	0	103	62	172	166	208	120	365	201	329	109	53	23	
-30	0	0	0	0	0	0	35	70	434	53	186	117	349	150	198	217	63	19	
-20	0	0	0	0	0	0	16	96	214	142	333	179	436	282	164	304	47	22	
-10	0	0	0	0	0	0	0	105	91	276	134	167	401	160	176	115	56	33	
0	0	0	0	0	0	0	0	73	74	76	54	66	176	168	268	48	70	9	
10	0	0	0	0	0	0	4	40	118	44	95	111	52	55	147	37	28	0	
20	0	0	0	0	2	65	0	157	59	95	21	35	175	15	48	70	4	0	
30	0	0	22	102	128	154	62	97	2	92	0	24	174	10	2	8	0	0	
40	0	0	100	62	1	131	114	51	69	130	10	126	101	0	0	0	0	0	
50	0	0	114	9	0	8	195	117	100	122	183	33	34	0	0	0	0	0	
60	0	0	6	0	0	0	155	136	44	85	135	87	41	0	0	0	0	0	
70	0	0	0	0	0	0	4	239	88	83	124	588	0	0	0	0	0	0	
80	0	0	0	0	0	0	0	114	346	235	217	46	0	0	0	0	0	0	
90	0	0	0	0	0	0	0	0	261	164	122	84	0	0	0	0	0	0	
100	0	0	0	0	0	0	0	16	131	208	144	19	0	0	0	0	0	0	
110	0	0	0	0	0	0	66	0	74	323	166	0	0	0	0	0	0	0	
120	0	0	0	0	23	30	31	28	80	137	311	20	0	0	0	0	0	0	
130	0	0	0	0	29	0	0	55	70	56	206	220	29	0	0	0	0	0	
140	0	0	4	0	34	265	295	99	82	35	38	110	181	0	0	0	0	0	
150	0	6	66	35	70	79	10	34	101	143	258	65	175	32	0	0	0	0	
160	0	17	0	23	78	103	142	51	87	40	80	88	1	145	0	0	0	0	
170	0	36	33	24	97	105	44	0	35	51	45	126	7	119	16	0	0	0	
180	0	19	0	24	87	199	135	131	10	52	47	63	46	19	87	0	0	0	

TABLE 1 (e)

TOTAL POINTS

NO. OF OBSERVATIONS= 306011.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	42	117	46	42	103	87	632	471	125	153	271	180	52	792	184	115	7	
-160	8	315	6	18	13	14	143	228	161	416	439	349	127	146	820	454	221	108	
-150	10	55	3	12	14	15	67	356	255	261	571	2208	143	168	781	580	317	151	
-140	3	13	5	1	21	45	29	242	28	55	85	994	246	422	518	1414	288	69	
-130	0	4	7	0	27	65	60	24	26	24	159	516	777	629	2183	1118	305	65	
-120	67	0	4	12	11	37	28	50	12	41	198	200	1817	3036	2131	882	261	86	
-110	474	512	0	8	7	52	37	54	32	52	263	522	2729	2555	8963	1239	250	126	
-100	165	449	0	18	15	78	43	28	226	203	354	452	2184	2475	7377	881	612	194	
-90	118	454	0	25	24	98	136	33	248	206	940	1405	3628	3978	3910	1076	529	436	
-80	75	99	0	39	14	113	133	217	330	421	867	1875	5468	4386	1613	689	530	207	
-70	16	6	4	166	76	608	390	1542	767	1181	1464	1595	4250	6267	1662	938	516	152	
-60	0	26	251	191	155	1176	362	407	445	664	2766	1419	3016	3706	1842	766	607	136	
-50	0	1	193	170	25	581	328	397	554	829	877	759	1755	2153	1655	777	322	48	
-40	0	188	240	13	19	48	897	381	836	466	575	398	1128	573	1380	596	180	61	
-30	0	49	9	36	8	23	111	419	1379	195	560	371	1020	434	713	924	193	53	
-20	0	18	0	11	16	5	92	312	621	424	935	548	1475	815	636	1278	220	64	
-10	0	0	0	7	26	33	28	324	272	880	562	640	1215	529	1021	523	198	98	
0	0	0	0	8	23	43	21	334	237	434	481	353	1874	1893	2833	373	221	57	
10	0	0	0	13	9	65	58	131	362	397	510	1690	1401	1167	2671	2007	96	18	
20	0	0	0	8	2	1167	494	658	554	659	293	540	687	1195	2220	4932	182	0	
30	0	0	22	109	129	1963	1545	798	253	451	110	90	609	636	1751	6777	1054	7	
40	0	0	164	73	19	181	935	550	1194	730	254	1165	1051	136	295	1456	53	2	
50	0	0	117	14	14	27	856	2008	274	399	554	105	422	169	196	557	27	0	
60	0	0	6	0	14	11	443	390	190	262	420	301	306	0	2	229	127	97	
70	0	0	6	2	82	1	51	308	272	246	386	1777	267	89	240	217	26	2	
80	0	0	4	54	5	45	35	195	721	1014	3157	1269	1822	16	22	168	23	1	
90	0	0	23	5	20	14	16	9	456	506	532	1593	173	29	112	125	106	4	
100	0	3	46	1	5	58	18	68	359	444	1340	677	337	13	21	12	45	3	
110	0	0	3	17	22	16	191	43	722	845	1111	821	855	10	300	14	603	0	
120	0	0	6	20	68	1012	249	91	355	409	561	1542	78	14	0	7	7	0	
130	0	0	0	4	122	130	122	233	296	382	1081	914	654	21	4	116	43	1	
140	0	0	10	31	113	820	590	549	445	309	125	306	775	40	1	48	25	0	
150	0	23	408	120	369	808	346	388	300	382	898	331	696	283	169	76	55	0	
160	5	67	12	132	195	747	658	193	296	189	270	220	15	475	122	101	328	0	
170	25	432	120	142	812	416	207	72	177	244	217	339	29	454	179	172	671	0	
180	3	164	8	89	2426	1798	552	536	150	186	175	185	133	62	415	37	305	0	

TABLE 1 (f)

DISTRIBUTION FOR YEARS 1900 THRU 1909

NO. OF OBSERVATIONS= 30374.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	13	0	0	5	0	0	83	13	0	0	5	6	4	0	4	0	0	
-160	0	12	0	2	2	0	0	22	27	28	13	38	0	17	31	29	0	0	
-150	0	10	0	2	3	0	3	3	0	51	37	281	1	7	43	29	0	0	
-140	0	0	0	1	5	0	0	72	17	0	15	13	12	4	3	54	0	0	
-130	0	0	0	0	11	0	0	0	12	3	0	21	10	13	349	38	0	0	
-120	0	0	0	3	3	0	0	0	0	15	8	23	104	317	42	0	0	0	
-110	0	0	0	1	0	0	0	0	5	11	8	15	170	404	452	4	0	0	
-100	0	0	0	0	0	13	0	0	9	0	0	81	514	441	517	39	3	0	
-90	0	0	0	3	0	13	2	0	8	0	90	148	1225	1130	142	20	3	0	
-80	0	0	0	2	0	0	4	16	18	42	147	260	1445	1083	20	0	0	0	
-70	0	0	0	1	0	20	0	30	24	163	43	76	677	1070	68	3	6	0	
-60	0	0	45	36	0	19	0	0	0	7	361	4	242	215	36	14	17	1	
-50	0	0	78	2	1	3	0	0	0	98	21	20	0	105	68	11	10	0	
-40	0	0	12	0	5	0	33	0	0	0	5	15	0	9	0	0	0	0	
-30	0	0	0	0	0	7	0	9	6	0	1	36	8	2	3	0	0	3	
-20	0	0	0	0	0	2	17	8	11	18	17	21	8	4	4	0	57	0	
-10	0	0	0	0	0	4	2	0	11	9	2	2	28	26	44	0	6	0	
0	0	0	0	0	0	2	6	9	1	12	1	0	74	75	174	0	0	0	
10	0	0	0	0	0	5	12	0	0	2	35	51	46	76	156	0	0	0	
20	0	0	0	0	0	601	273	9	37	28	33	0	11	160	88	0	9	0	
30	0	0	0	0	1	1559	1036	228	0	32	0	0	36	4	0	88	16	1	
40	0	0	0	0	9	33	403	271	441	152	0	67	15	51	42	25	4	0	
50	0	0	0	0	9	0	14	515	3	7	12	6	83	35	4	32	2	0	
60	0	0	0	0	3	0	50	0	1	0	0	33	65	0	0	77	20	30	
70	0	0	0	0	59	0	12	0	0	0	0	207	168	6	35	9	4	0	
80	0	0	3	7	5	11	3	0	0	46	1207	824	717	10	0	0	2	0	
90	0	0	22	5	3	0	0	0	0	0	168	889	0	6	2	1	5	0	
100	0	0	3	1	4	0	0	0	3	48	414	468	24	2	3	4	13	0	
110	0	0	0	1	2	0	0	3	163	39	33	12	66	0	81	13	5	0	
120	0	0	0	3	0	0	0	0	94	21	4	232	19	0	0	0	0	0	
130	0	0	0	4	0	0	0	9	60	56	20	22	107	1	2	3	1	1	
140	0	0	0	6	0	0	1	0	42	43	12	13	50	3	0	0	8	0	
150	0	3	2	2	0	17	0	0	6	14	41	10	8	0	44	0	4	0	
160	0	16	3	4	0	3	0	0	0	18	5	0	4	2	40	1	0	0	
170	15	148	6	30	139	2	3	8	14	67	0	0	4	6	35	20	0	0	
180	0	36	6	7	456	272	12	57	16	14	4	6	0	4	7	2	2	0	

TABLE 2 (a)

DISTRIBUTION FOR YEARS 1910 THRU 1919

NO. OF OBSERVATIONS= 51979.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	14	34	20	8	27	17	84	22	27	4	0	0	21	20	4	0	0	
-160	0	28	6	16	0	8	11	4	0	0	0	8	21	9	70	2	0	0	
-150	0	14	3	9	0	15	13	10	0	0	94	349	0	0	33	7	0	0	
-140	0	0	5	0	0	41	3	102	7	0	7	6	0	7	4	106	0	0	
-130	0	0	6	0	16	31	30	5	8	21	15	0	1	25	133	6	0	0	
-120	0	0	4	9	8	22	28	37	12	26	13	5	119	718	805	17	1	0	
-110	0	0	0	7	7	29	22	32	27	41	42	12	148	878	5404	29	12	0	
-100	0	0	0	18	15	33	11	0	0	29	5	0	426	785	4230	0	8	1	
-90	0	0	0	22	23	12	20	24	10	38	15	105	827	1309	1390	8	3	1	
-80	0	0	0	37	14	33	42	16	29	36	12	130	1560	891	142	6	0	0	
-70	0	0	3	51	22	200	50	534	176	215	37	15	671	1327	21	28	0	0	
-60	0	0	0	98	67	528	81	180	171	128	243	35	114	317	8	19	0	0	
-50	0	1	5	142	20	144	146	111	81	43	7	11	55	32	142	0	0	0	
-40	0	176	162	13	0	28	321	109	193	33	37	35	47	20	12	0	0	0	
-30	0	32	9	32	0	8	12	132	58	36	41	16	53	23	4	4	0	0	
-20	0	3	0	11	7	3	7	22	0	13	15	0	71	15	11	80	0	0	
-10	0	0	0	7	16	11	0	26	19	62	78	59	22	30	51	13	0	0	
0	0	0	0	9	20	13	15	109	18	89	76	0	105	51	792	29	6	0	
10	0	0	0	9	9	35	16	7	27	156	80	154	146	80	181	7	13	0	
20	0	0	0	8	0	160	20	122	219	255	137	0	54	159	185	26	26	0	
30	0	0	0	7	0	7	42	105	100	18	86	18	106	358	78	2686	186	0	
40	0	0	0	11	6	3	8	1	7	51	223	459	278	6	52	668	0	0	
50	0	0	0	5	5	2	0	40	1	12	23	0	110	22	40	462	0	0	
60	0	0	0	0	11	2	88	8	16	14	6	3	7	0	0	26	12	5	
70	0	0	0	2	20	0	17	0	0	0	20	30	13	1	50	55	9	0	
80	0	0	0	12	0	24	16	24	14	191	992	128	611	4	10	36	1	0	
90	0	0	0	0	17	5	3	4	19	135	16	260	0	16	31	105	16	0	
100	0	0	30	0	1	46	11	3	0	24	454	74	2	3	2	7	0	2	
110	0	0	0	16	20	8	11	19	168	45	241	305	294	10	79	0	457	0	
120	0	0	0	17	2	408	128	12	19	0	18	594	35	10	0	0	4	0	
130	0	0	0	0	24	56	119	61	41	6	162	111	113	11	0	11	2	0	
140	0	0	0	22	16	234	182	197	0	28	7	7	16	2	0	2	1	0	
150	0	7	221	9	73	290	133	83	23	0	132	32	30	0	112	0	1	0	
160	5	0	9	21	0	101	68	34	29	2	19	1	8	8	55	7	0	0	
170	10	163	28	12	31	12	30	32	39	47	48	39	12	24	43	50	2	0	
180	3	68	2	11	453	13	22	60	67	16	29	18	6	4	17	0	2	0	

TABLE 2 (b)

DISTRIBUTION FOR YEARS 1920 THRU 1929

NO. OF OBSERVATIONS= 25585.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	0	0	0	9	0	23	133	23	12	0	12	12	3	14	107	31	0	
-160	0	60	0	0	8	3	19	55	1	0	19	54	33	0	34	22	0	0	
-150	0	0	0	0	10	0	45	31	59	21	12	221	29	7	68	9	0	0	
-140	0	0	0	0	16	4	26	41	4	55	0	30	39	4	9	13	0	0	
-130	0	0	0	0	0	34	30	19	6	0	36	52	25	10	483	62	0	0	
-120	0	0	0	0	0	15	0	13	0	0	0	0	145	210	71	144	0	0	
-110	0	0	0	0	0	23	15	22	0	0	0	30	262	165	827	313	0	0	
-100	0	0	0	0	0	32	31	28	17	0	0	116	134	180	751	8	0	0	
-90	0	0	0	0	1	12	0	9	23	13	169	71	182	205	529	3	0	0	
-80	0	0	0	0	0	8	10	13	24	97	126	162	519	230	21	3	0	0	
-70	0	0	0	23	9	21	30	196	45	190	138	103	324	420	0	153	105	0	
-60	0	0	0	16	22	58	55	21	34	11	262	0	313	226	36	38	5	0	
-50	0	0	0	25	2	125	24	50	94	59	30	0	5	15	77	36	0	0	
-40	0	0	0	0	14	19	76	16	49	0	17	2	22	16	10	0	0	0	
-30	0	0	0	4	8	8	5	24	9	8	19	11	3	9	6	3	0	0	
-20	0	0	0	0	9	0	20	4	0	0	0	0	99	8	0	8	3	0	
-10	0	0	0	0	10	18	26	3	0	35	47	94	16	5	45	10	0	0	
0	0	0	0	0	2	26	0	16	0	109	152	3	569	672	413	34	0	0	
10	0	0	0	0	0	23	12	22	3	60	58	0	86	201	101	0	0	0	
20	0	0	0	0	0	125	73	102	103	59	39	0	13	62	530	447	24	0	
30	0	0	0	0	0	68	32	92	44	4	23	0	31	187	556	278	22	3	
40	0	0	0	0	0	12	21	57	56	7	0	87	135	30	66	208	0	2	
50	0	0	0	0	0	17	154	192	3	19	9	0	36	18	42	50	8	0	
60	0	0	0	0	0	9	40	15	0	3	8	0	142	0	2	111	63	3	
70	0	0	0	0	0	0	18	11	19	19	8	9	39	6	40	144	8	0	
80	0	0	0	0	0	10	16	0	0	118	109	48	129	2	12	132	15	0	
90	0	0	0	0	0	9	12	5	0	16	12	33	74	4	71	19	39	0	
100	0	0	0	0	0	12	0	8	26	56	126	28	197	0	16	1	0	0	
110	0	0	0	0	0	8	0	21	105	37	303	5	184	0	38	1	0	0	
120	0	0	0	0	2	310	9	0	30	16	0	133	0	0	0	7	3	0	
130	0	0	0	0	14	19	3	4	15	10	72	65	143	0	0	34	34	0	
140	0	0	0	3	6	157	13	25	31	20	0	0	0	0	1	40	16	0	
150	0	0	0	8	36	138	96	58	18	6	24	36	47	0	13	19	39	0	
160	0	0	0	0	7	22	29	13	17	15	13	0	0	4	9	30	313	0	
170	0	0	0	0	23	0	27	20	15	8	11	5	0	4	40	84	669	0	
180	0	0	0	0	177	13	0	6	28	0	12	0	0	4	0	18	301	0	

TABLE 2 (c)

DISTRIBUTION FOR YEARS 1930 THRU 1939

NO. OF OBSERVATIONS= 22777.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	0	0	0	0	0	0	55	0	0	0	3	0	0	24	0	0	0	
-160	8	203	0	0	0	0	0	0	0	0	0	0	0	0	123	26	0	0	
-150	10	26	0	0	0	0	0	0	0	0	6	94	0	0	63	6	33	0	
-140	3	13	0	0	0	0	0	23	0	0	0	0	0	0	3	16	0	0	
-130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	222	21	0	0	
-120	0	0	0	0	0	0	0	0	0	0	0	0	95	347	57	12	0	0	
-110	0	0	0	0	0	0	0	0	0	0	0	9	355	210	109	9	0	0	
-100	0	0	0	0	0	0	1	0	0	0	33	78	177	259	60	0	0	0	
-90	0	0	0	0	0	0	0	0	2	0	121	138	366	262	33	9	0	0	
-80	0	0	0	0	0	0	0	0	12	40	25	187	341	310	3	2	3	0	
-70	0	0	0	61	18	19	3	71	115	36	55	21	253	513	9	13	25	0	
-60	0	0	0	11	38	118	40	31	40	86	108	0	0	105	13	9	4	0	
-50	0	0	0	0	0	42	11	21	18	47	21	0	0	3	16	33	0	3	
-40	0	0	22	0	0	0	67	15	30	0	0	0	0	0	0	68	0	0	
-30	0	0	0	0	0	0	0	25	34	0	0	0	0	0	0	13	0	0	
-20	0	0	0	0	0	0	0	0	0	0	0	0	42	0	0	0	19	0	
-10	0	0	0	0	0	0	0	0	0	0	16	29	0	0	39	0	19	6	
0	0	0	0	0	0	0	0	0	0	1	62	102	268	95	119	37	14	30	
10	0	0	0	0	0	0	0	0	3	22	36	796	26	317	441	81	0	18	
20	0	0	0	0	0	109	80	12	0	0	5	32	17	579	923	1108	23	0	
30	0	0	0	0	0	71	218	67	8	165	0	2	4	26	233	3302	51	3	
40	0	0	0	0	0	0	157	79	214	65	8	56	157	13	48	353	3	0	
50	0	0	0	0	0	0	404	821	0	19	33	14	112	32	43	13	17	0	
60	0	0	0	0	0	0	40	19	0	0	0	0	0	0	0	15	29	26	
70	0	0	0	0	0	0	0	0	0	0	0	12	12	16	48	9	5	2	
80	0	0	0	0	0	0	0	0	0	0	54	53	176	0	0	0	5	1	
90	0	0	0	0	0	0	0	0	0	0	0	129	99	0	0	0	36	4	
100	0	0	0	0	0	0	0	0	0	9	15	46	109	0	0	0	32	1	
110	0	0	0	0	0	0	0	0	61	36	82	233	117	0	35	0	118	0	
120	0	0	0	0	0	90	4	0	0	21	11	299	20	3	0	0	0	0	
130	0	0	0	0	0	18	0	0	0	16	73	109	137	0	0	20	0	0	
140	0	0	0	0	0	84	29	23	0	30	3	6	0	0	0	6	0	0	
150	0	0	0	0	12	60	47	6	17	12	18	36	39	28	0	57	11	0	
160	0	0	0	0	0	73	24	3	18	51	0	0	0	0	12	26	15	0	
170	0	0	0	0	28	0	13	12	13	1	9	0	0	0	8	18	0	0	
180	0	0	0	0	66	26	0	3	10	9	3	0	0	0	3	17	0	0	

TABLE 2 (d)

DISTRIBUTION FOR YEARS 1940 THRU 1949

NO. OF OBSERVATIONS= 20322.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	1	0	0	18	0	0	40	0	0	0	9	0	0	30	0	0	1	
-160	0	8	0	0	3	0	0	0	0	0	0	0	0	0	47	41	7	0	
-150	0	0	0	0	0	0	0	0	0	0	0	55	0	0	52	43	18	0	
-140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	272	20	0	
-130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	139	68	0	0	
-120	0	0	0	0	0	0	0	0	0	0	0	0	36	253	9	106	5	0	
-110	0	0	0	0	0	0	0	0	0	0	0	3	125	214	45	89	13	0	
-100	0	0	0	0	0	0	0	0	0	0	42	19	96	98	40	44	18	0	
-90	0	0	0	0	0	0	0	0	16	0	143	84	128	113	6	56	49	0	
-80	0	0	0	0	0	0	0	0	11	43	142	82	158	348	3	24	52	0	
-70	0	6	1	13	15	22	27	82	87	135	76	23	198	639	3	45	22	0	
-60	0	26	30	1	7	178	70	42	12	16	114	0	17	162	14	52	34	1	
-50	0	0	20	1	0	125	19	13	6	26	0	0	0	30	10	73	3	0	
-40	0	0	37	0	0	0	69	18	12	0	0	0	0	0	4	27	0	0	
-30	0	0	0	0	0	0	0	15	19	0	0	0	0	0	0	4	0	0	
-20	0	0	0	0	0	0	0	0	0	0	1	1	36	0	0	0	0	0	
-10	0	0	0	0	0	0	0	0	0	3	16	11	0	0	40	0	0	0	
0	0	0	0	0	0	1	0	0	0	14	28	46	268	370	151	39	0	0	
10	0	0	0	0	0	0	0	0	3	43	34	296	853	201	1081	936	0	0	
20	0	0	0	0	0	63	23	3	37	52	16	365	76	121	213	1196	10	0	
30	0	0	0	0	0	33	39	49	79	0	0	0	6	12	832	165	359	0	
40	0	0	0	0	0	0	54	13	254	128	0	75	94	8	31	181	24	0	
50	0	0	0	0	0	0	1	47	0	0	4	0	0	35	39	0	0	0	
60	0	0	0	0	0	0	40	0	44	0	4	2	0	0	0	0	3	25	
70	0	0	0	0	3	0	0	0	1	3	1	19	19	32	39	0	0	0	
80	0	0	0	15	0	0	0	0	0	25	116	85	189	0	0	0	0	0	
90	0	0	1	0	0	0	0	0	0	9	20	65	0	3	8	0	10	0	
100	0	0	6	0	0	0	0	25	0	4	0	10	5	8	0	0	0	0	
110	0	0	2	0	0	0	0	0	25	21	45	266	194	0	39	0	19	0	
120	0	0	3	0	0	99	21	0	3	15	16	224	4	1	0	0	0	0	
130	0	0	0	0	0	33	0	9	0	2	11	84	52	9	2	22	6	0	
140	0	0	0	0	2	54	9	46	0	2	0	0	0	17	0	0	0	0	
150	0	0	0	0	0	89	25	3	1	0	20	30	40	26	0	0	0	0	
160	0	0	0	27	0	146	18	0	0	0	0	1	0	0	6	17	0	0	
170	0	6	0	27	338	0	0	0	2	3	0	0	0	0	0	0	0	0	
180	0	0	0	0	979	767	0	0	0	0	0	1	0	0	59	0	0	0	

TABLE 2 (e)

DISTRIBUTION FOR YEARS 1950 THRU 1959

NO. OF OBSERVATIONS= 97447.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	0	0	0	2	76	47	168	208	0	57	105	140	24	563	67	84	6	
-160	0	4	0	0	0	3	113	147	55	250	82	155	0	47	447	330	213	99	
-150	0	5	0	1	1	0	6	312	196	189	372	554	37	90	463	469	266	138	
-140	0	0	0	0	0	0	0	4	0	0	63	436	123	355	498	793	226	59	
-130	0	4	1	0	0	0	0	0	0	0	97	210	460	503	841	821	238	47	
-120	0	0	0	0	0	0	0	0	0	0	82	155	909	1033	923	537	237	49	
-110	0	0	0	0	0	0	0	0	0	0	116	453	1090	476	1413	647	210	74	
-100	0	0	0	0	0	0	0	0	61	96	111	146	476	442	1145	632	420	160	
-90	0	0	0	0	0	0	0	0	89	155	351	612	568	708	1106	740	367	427	
-80	0	0	0	0	0	1	0	115	200	163	415	1043	781	1077	694	567	363	177	
-70	0	0	0	17	12	174	170	459	320	389	894	1019	1448	1548	830	685	271	95	
-60	0	0	176	29	21	200	116	133	123	166	1396	1180	1714	1590	1003	207	315	114	
-50	0	0	90	0	2	48	114	80	101	341	704	728	1123	1182	672	328	167	45	
-40	0	12	7	0	0	1	153	69	442	355	416	346	826	335	990	219	174	48	
-30	0	17	0	0	0	0	85	24	840	151	377	308	715	302	498	641	193	39	
-20	0	15	0	0	0	0	48	59	465	337	784	497	980	620	436	863	141	42	
-10	0	0	0	0	0	0	0	0	93	133	606	304	189	794	174	543	339	156	78
0	0	0	0	0	0	1	1	0	82	114	63	0	36	429	386	840	168	151	27
10	0	0	0	4	0	2	18	87	115	15	4	201	89	148	246	980	35	0	
20	0	0	0	0	2	73	25	65	41	103	0	43	58	76	78	2033	90	0	
30	0	0	7	14	92	179	63	111	22	86	1	0	14	29	24	219	420	0	
40	0	0	91	62	4	78	85	84	138	147	6	78	127	28	56	21	22	0	
50	0	0	58	9	0	8	113	146	8	110	10	2	0	27	28	0	0	0	
60	0	0	5	0	0	0	123	203	0	117	7	32	0	0	0	0	0	8	
70	0	0	6	0	0	1	4	133	99	118	0	5	16	28	28	0	0	0	
80	0	0	1	20	0	0	0	63	152	130	81	12	0	0	0	0	0	0	
90	0	0	0	0	0	0	1	0	156	167	5	0	0	0	0	0	0	0	
100	0	3	7	0	0	0	7	0	68	169	69	0	0	0	0	0	0	0	
110	0	0	1	0	0	0	180	0	60	135	138	0	0	0	28	0	4	0	
120	0	0	3	0	64	105	87	79	4	147	223	5	0	0	0	0	0	0	
130	0	0	0	0	84	4	0	94	0	241	340	272	47	0	0	26	0	0	
140	0	0	3	0	89	258	247	110	245	186	0	116	537	18	0	0	0	0	
150	0	0	70	0	151	95	45	238	220	253	178	23	271	229	0	0	0	0	
160	0	0	0	26	141	310	369	143	232	0	0	185	0	257	0	20	0	0	
170	0	9	0	2	155	402	35	0	94	28	62	91	13	216	53	0	0	0	
180	0	3	0	0	134	613	360	242	29	42	127	12	67	29	193	0	0	0	

TABLE 2 (f)

DISTRIBUTION FOR YEARS 1960 THRU 1961

NO. OF OBSERVATIONS= 57527.

	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-170	0	21	83	26	0	0	0	69	205	86	92	137	22	0	141	2	0	0	
-160	0	0	0	0	0	0	0	0	78	138	325	94	73	73	68	4	1	9	
-150	0	0	0	0	0	0	0	0	0	0	50	654	76	64	59	17	0	13	
-140	0	0	0	0	0	0	0	0	0	0	0	509	72	52	1	160	42	10	
-130	0	0	0	0	0	0	0	0	0	0	11	233	281	78	16	102	67	18	
-120	67	0	0	0	0	0	0	0	0	0	95	17	409	158	224	66	18	37	
-110	474	512	0	0	0	0	0	0	0	0	97	0	579	208	713	148	15	52	
-100	165	449	0	0	0	0	0	0	139	78	163	12	361	270	634	158	163	33	
-90	118	454	0	0	0	61	114	0	100	0	51	247	332	251	704	240	107	8	
-80	75	99	0	0	0	71	77	57	36	0	0	11	664	447	730	87	112	30	
-70	16	0	0	0	0	152	110	170	0	53	221	338	679	750	731	11	87	57	
-60	0	0	0	0	0	75	0	0	65	250	282	200	616	1091	732	427	232	20	
-50	0	0	0	0	0	94	14	122	254	215	94	0	572	786	670	296	142	0	
-40	0	0	0	0	0	0	178	154	110	78	100	0	233	193	364	282	6	13	
-30	0	0	0	0	0	0	9	190	413	0	122	0	241	98	202	259	0	11	
-20	0	0	0	0	0	0	0	219	145	56	118	29	239	168	185	327	0	22	
-10	0	0	0	0	0	0	0	202	109	165	99	256	355	294	259	161	17	14	
0	0	0	0	0	0	0	0	118	104	146	162	166	161	244	344	66	50	0	
10	0	0	0	0	0	0	0	15	211	99	263	192	155	144	465	3	48	0	
20	0	0	0	0	0	36	0	345	117	162	63	100	458	38	203	122	0	0	
30	0	0	15	88	36	46	115	146	0	146	0	70	412	20	28	39	0	0	
40	0	0	73	0	0	55	207	45	84	180	17	343	245	0	0	0	0	0	
50	0	0	59	0	0	0	170	247	259	232	463	83	81	0	0	0	0	0	
60	0	0	1	0	0	0	62	145	129	128	395	231	92	0	0	0	0	0	
70	0	0	0	0	0	0	0	164	153	106	357	1495	0	0	0	0	0	0	
80	0	0	0	0	0	0	0	108	555	504	598	119	0	0	0	0	0	0	
90	0	0	0	0	0	0	0	0	281	179	311	217	0	0	0	0	0	0	
100	0	0	0	0	0	0	0	32	262	134	262	51	0	0	0	0	0	0	
110	0	0	0	0	0	0	0	0	140	532	269	0	0	0	0	0	0	0	
120	0	0	0	0	0	0	0	0	205	189	289	55	0	0	0	0	0	0	
130	0	0	0	0	0	0	0	56	180	51	403	251	55	0	0	0	0	0	
140	0	0	7	0	0	33	109	148	127	0	103	164	172	0	0	0	0	0	
150	0	18	115	101	97	119	0	0	15	97	485	164	261	0	0	0	0	0	
160	0	51	0	54	47	92	150	0	0	103	233	33	3	204	0	0	0	0	
170	0	106	86	71	98	0	99	0	0	90	87	204	0	204	0	0	0	0	
180	0	57	0	71	161	94	158	168	0	105	0	148	60	21	136	0	0	0	

TABLE 2 (g)

TABLE 3 DISTRIBUTION BY YEAR

YEAR	DECLINATION	DIP	H	V	F	TOTAL
1900	764.	568.	509.	34.	0.	1875.
1901	700.	396.	365.	35.	0.	1496.
1902	837.	620.	551.	50.	0.	2058.
1903	2009.	1561.	1445.	51.	0.	5066.
1904	962.	793.	782.	49.	0.	2586.
1905	1209.	1072.	1043.	48.	0.	3372.
1906	1082.	1062.	1053.	48.	0.	3245.
1907	1020.	1003.	958.	46.	0.	3027.
1908	1148.	890.	957.	54.	0.	3049.
1909	2195.	1154.	1197.	54.	0.	4600.
1910	2578.	1591.	1638.	51.	0.	5858.
1911	2355.	1075.	1087.	61.	0.	4578.
1912	2758.	1321.	1401.	63.	0.	5543.
1913	3038.	1305.	1350.	51.	0.	5744.
1914	3116.	1315.	1397.	49.	0.	5877.
1915	3933.	1493.	1621.	49.	0.	7096.
1916	3345.	1214.	1217.	53.	0.	5829.
1917	2563.	1056.	1095.	51.	0.	4765.
1918	2096.	705.	730.	51.	0.	3582.
1919	1626.	699.	730.	52.	0.	3107.
1920	1996.	759.	912.	53.	0.	3720.
1921	1620.	659.	712.	49.	0.	3040.
1922	1560.	877.	880.	55.	0.	3372.
1923	1077.	841.	897.	55.	0.	2870.
1924	1366.	834.	877.	57.	0.	3134.
1925	671.	442.	533.	170.	0.	1816.
1926	812.	514.	545.	62.	0.	1933.
1927	604.	515.	530.	59.	0.	1708.
1928	704.	551.	574.	58.	0.	1887.
1929	926.	579.	538.	62.	0.	2105.
1930	2103.	1636.	1659.	59.	0.	5457.
1931	887.	297.	374.	80.	0.	1638.
1932	456.	290.	294.	57.	0.	1097.
1933	583.	301.	303.	84.	0.	1271.
1934	959.	473.	465.	68.	0.	1965.
1935	1220.	825.	845.	59.	0.	2949.
1936	849.	344.	428.	78.	0.	1699.
1937	648.	234.	526.	104.	0.	1512.
1938	1639.	289.	618.	359.	0.	2905.
1939	1389.	349.	428.	118.	0.	2284.
1940	994.	438.	543.	72.	0.	2047.
1941	699.	314.	370.	74.	0.	1457.
1942	776.	379.	540.	183.	0.	1878.
1943	1025.	473.	646.	145.	0.	2289.
1944	2153.	541.	561.	58.	0.	3313.
1945	895.	539.	572.	113.	0.	2119.
1946	725.	394.	434.	135.	0.	1688.
1947	771.	391.	535.	186.	0.	1883.
1948	916.	362.	588.	177.	0.	2043.
1949	733.	176.	449.	247.	0.	1605.
1950	3059.	1455.	1571.	1233.	1121.	8439.
1951	4491.	4372.	303.	137.	4110.	13413.
1952	1282.	516.	564.	91.	0.	2453.
1953	2861.	2010.	853.	657.	1823.	8204.
1954	3015.	1599.	1681.	1528.	1415.	9238.
1955	2358.	1417.	1258.	1030.	1252.	7315.
1956	3373.	3827.	242.	115.	3911.	11468.
1957	2306.	1322.	1171.	1123.	1368.	7290.
1958	2821.	1340.	2140.	2004.	1969.	10274.
1959	4203.	4323.	1199.	1195.	8433.	19353.
1960	7518.	7220.	1917.	1958.	10681.	29294.
1961	7589.	7504.	2090.	2118.	8932.	28233.
1962	0.	0.	0.	0.	0.	0.

TABLE 4

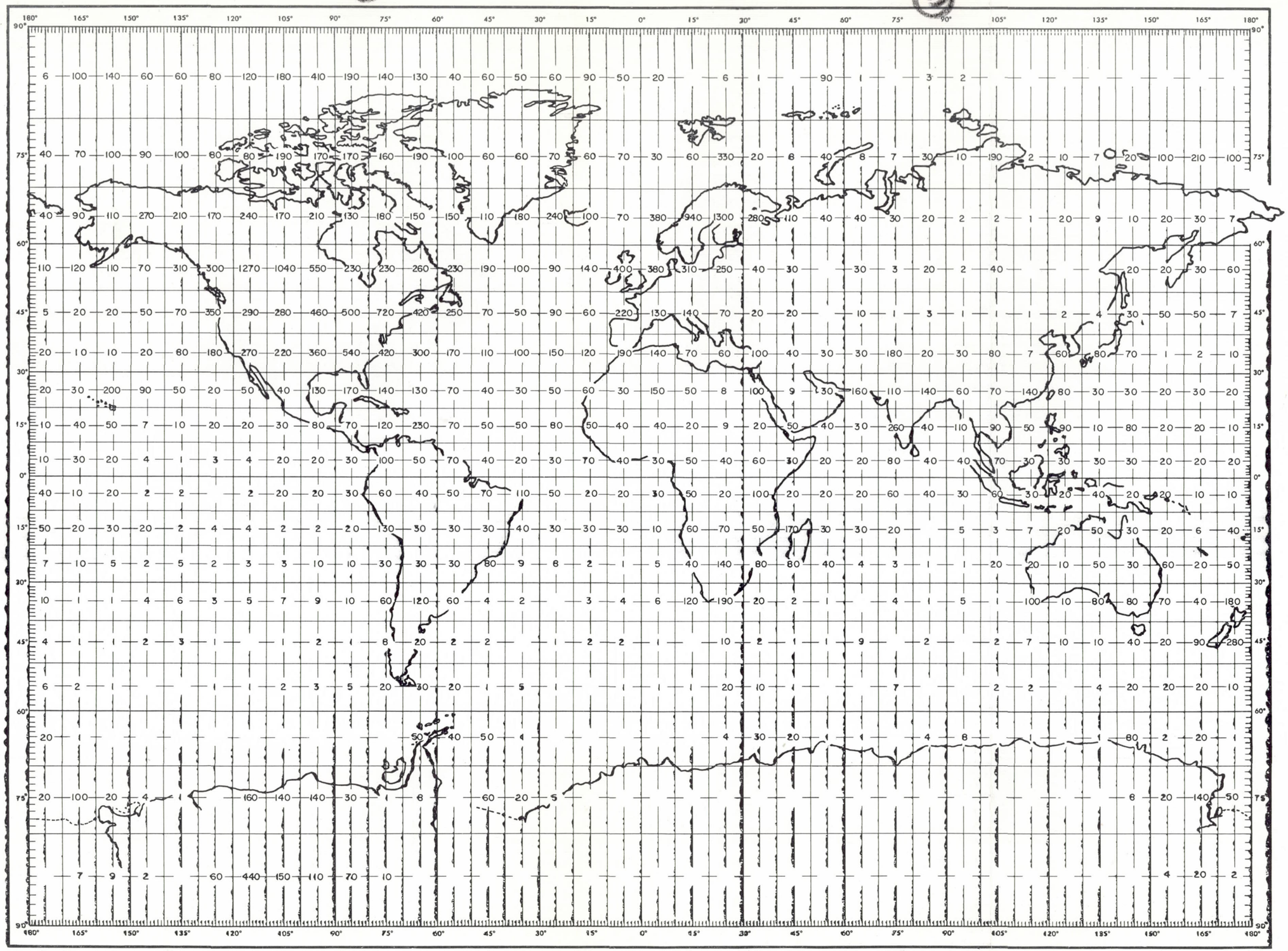
ALTITUDE DISTRIBUTION

Altitude(km)	Declination	Inclination	Horizontal	Vertical	Total Field	Sum
0 (surface)	78243	38948	43294	6044	2741	169270
0-1	704	842	201	204	1084	3035
1-2	2202	1997	642	668	3040	8549
2-3	18281	16051	6199	6289	18677	65497
3-4	9229	7736	3532	3662	8559	32718
4-5	1673	1757	389	417	1920	6156
5-6	1665	1956	15	17	2043	5696
6-7	3811	3959	19	24	3986	11799
7-8	158	168	0	0	168	494
> 8(satellite)					2797	2797

Thus, for an equatorial block, where one degree equals 111 km, a value of 1000 for a 10^{o} block would represent data points at an average of approximately 10 km intervals. It can be seen from the figure that the density in areas near the magnetic poles compares favorably with that over most of the larger land masses. The numbers above 10 are rounded to the nearest 10 $\left[\text{obs}/10^{5}\ \text{km}^{2}\right]$.

TABLE 5

LATITUDE	AREA (10^{5} km)
0^{o}-10^{o}	12.3
10^{o}-20^{o}	11.9
20^{o}-30^{o}	11.2
30^{o}-40^{o}	10.1
40^{o}-50^{o}	8.7
50^{o}-60^{o}	7.1
60^{o}-70^{o}	5.2
70^{o}-80^{o}	3.2
80^{o}-90^{o}	1.1



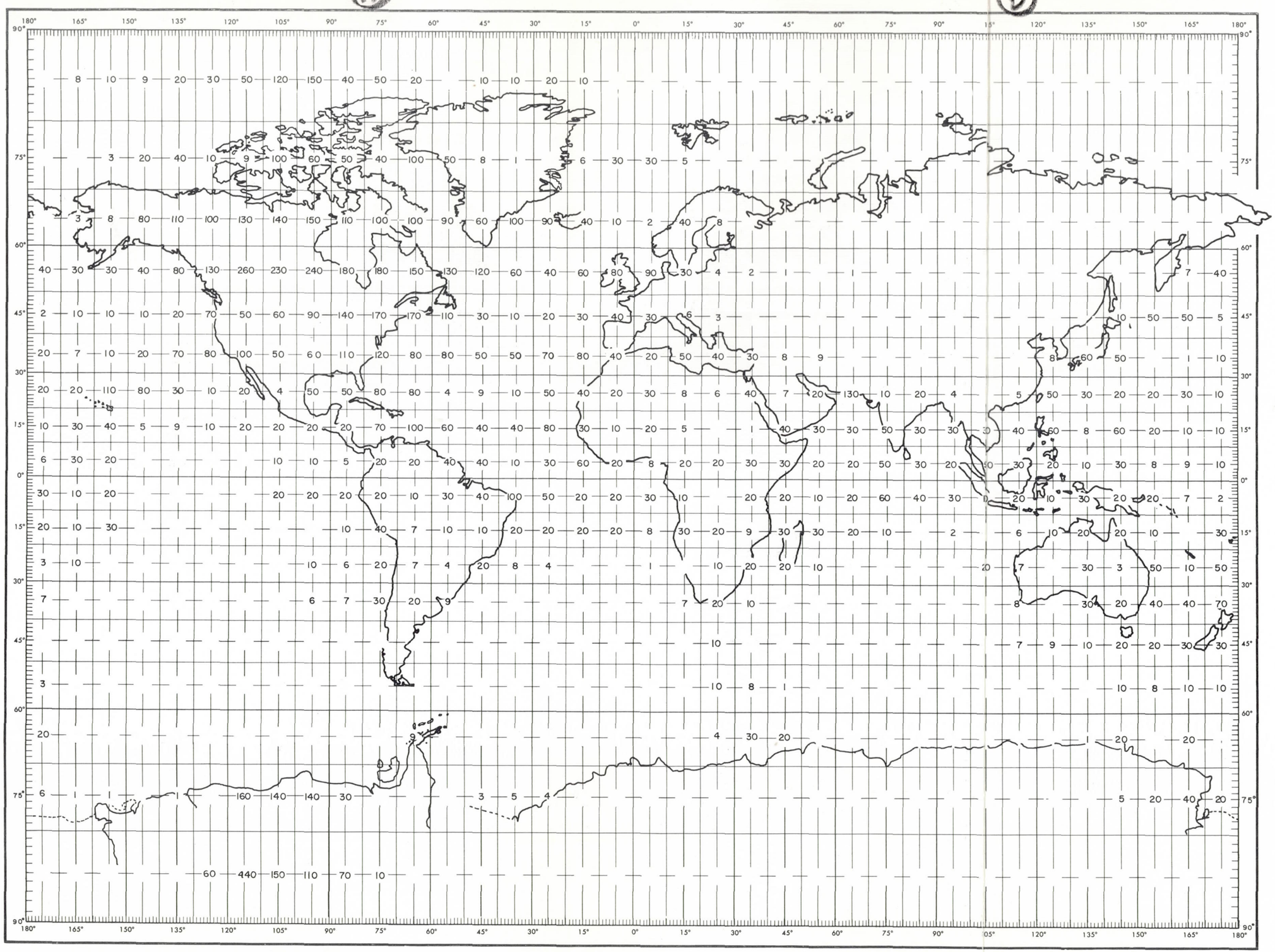
DENSITY OF MAGNETIC SURVEY OBSERVATIONS 1900-1961 (OBS PER $10^5 km^2$)

FIGURE 1

VI. RECOMMENDATIONS FOR FUTURE SURVEYS

Vestine (1961) has suggested that data obtained since 1955.0 be considered as part of the World Magnetic Survey. Figure 2 shows the density of data per 10^5 km^2 in 10^o squares since 1955, and hence, by Vestine's criterion, a tabulation of the coverage already achieved by the WMS. In order to obtain the desired accurate representation of the field at ionospheric altitudes and above, a minimum grid spacing of 100 km should be achieved. This would mean raising the numbers in each block of Figure 2 to 12 or more. It can readily be seen from this figure that there are large areas over the globe where this minimum criterion is not yet met. Detailed recommendations for new surveys must of course be made bearing in mind not only the density of observations in a given area but also such considerations as the usefulness of past observations, the existence of data taken but not available, and known firm plans for surveys. The usefulness of past observations is a complex subject involving not only their accuracy and space-time distribution but also the rates of secular change. The needs can thus best be defined in relation to given areas. The purpose of this report is to be a general guide and not to delve into these questions in great detail.

The most striking gaps in Figure 2 appear in the southern hemisphere. It points out that to equalize the distributions it would be useful to concentrate the major efforts in these



DENSITY OF MAGNETIC SURVEY OBSERVATIONS 1955-1961 (OBS PER $10^5 km^2$)

FIGURE 2

areas, even if some of the high density areas were temporarily neglected. A point worthy of mention in this connection is that almost all of the data south of 30^{o}S latitude is scalar B as a result of proton magnetometer measurements by ship, aircraft, and satellite. There is indication that the Zarya data (Benkova and Tyurmina, 1961) will be helpful in filling in the gap in the Indian Ocean and in some regions of the south Atlantic down to about 40^{o}S. The rest of the vast regions of the Pacific and Antarctic need much further work.

The region of the Asian landmass is one where, hopefully, it will be possible to obtain data already in existence but not yet published.

There are also surprising gaps over other regions such as South America, Africa, Australia and Greenland where one would normally expect a better coverage. It is hoped that this report will be useful in bringing forth existing data in these and other areas.

REFERENCES

Beńkova, N. P., and L. O. Tyurmina, Analytical representation of the geomagnetic field over the territory of the Soviet Union for the 1958 epoch, Geomagnetism and Aeronomy, Vol. 1, 81-96, 1961.

Cain, J. C., I. R. Shapiro, J. D. Stolarik, and J. P. Heppner, Vanguard 3 magnetic field observations, J. Geophys. Research, 67, 5055-5069, 1962.

Nagata, T., T. Oguti, and S. Kakinuma, Results of geomagnetic total force surveys over Southern Ocean, Indian Ocean and South China Sea, National Antarctic Committee, Science Council of Japan, March, 1961.

Vestine, E. H., Instruction manual on World Magnetic Survey, Union Geodesique et Geophysique Internationale, N°11, August, 1961.